still brighter than Venus at its maximum brilliancy, like a suddenly appearing flame in a white colour. The bursting-point I could sharply determine 1½° below the middle of the line *α Pisc.* – γ *Ceti*, in the given direction; the mistake being not greater than one degree.

Accident having favoured me, looking sharply as I was in the direction of the phenomenon, my observation will, perhaps, have some importance, if positions of the same fire-ball have been taken by English observers. H. T. H. GRONEMAN

Groningen (Netherlands), March 4

Sunshine

IT may interest your readers and the Fellows of the Meteorological Society to know that "the sun is always shining somewhere," even though we have so little demonstration here. In a letter received from Adelaide, from a reliable observer, I note the following:—

"Last Tuesday, January 20, was a cooker! 113°·5 in the shade, and 172° in the sun, the highest ever registered here; the latter being within 40° of the boiling-point of water."

CHAS. COPPOCK

Grosvenor Road, Highbury New Park, March 5

Lines of Force due to a Small Magnet

REFERRING to my communication in NATURE, vol. xxi. p. 370, the value of y, for which the radius of curvature (ρ) is a maximum, should have been $y = \cdot 317\ C$, not $432\ C$ as stated.

Glasgow, February 27 JOHN BUCHANAN

Artificial Diamonds

I READ with great surprise a paragraph in NATURE, vol. xxi. p. 409, referring to an investigation which I am now making on the artificial production of various crystalline forms of carbon, and I write to disclaim all responsibility for statements which have been published without my knowledge or consent.

R. SYDNEY MARSDEN

University College, Bristol, February 27

[The correspondent who sent us the paragraph in question sent it in good faith, believing the matter to be to that extent public.—ED.]

JAS. ROCK.—The galls which your gardener found growing on the *root* of an oak-tree, about six inches below the surface of the ground, are probably galls produced by *Biorhiza aptera*.

J. W. WYATT.—The appearance in the specimen of a decayed ash bough is caused by the mycelium of *Helotium æruginosum*, Fr. [= *Peziza æruginosa*, Fr.]. See Cooke, "Handbook of British Fungi," pp. 708, 709; "Official Guide to the Kew Museums," p. 81.

PICTET'S PROPOSAL TO DISSOCIATE THE METALLOID ELEMENTS

THE task set before me is to expound in as simple and intelligible language as possible the remarkable train of reasoning which has led M. Raoul Pictet, of Geneva, to the conclusion that the so-called metalloids are really not elementary bodies at all, but capable of dissociation into simpler forms. During the last two years M. Pictet has published several important memoirs upon different branches of thermo-dynamics, and has, as is well-known, in his researches on the liquefaction of oxygen and of hydrogen shown the fruitfulness of the ideas which have thus occupied him. He is at the present moment engaged upon a large volume entitled *Synthèse de la Chaleur*, a work in which it is sought to deduce all the known laws of heat from the general principles of theoretical mechanics, by finding true mathematical definitions for the quantities which hitherto have been usually expressed as simple experimental matters. Thus the terms "temperature," "specific heat," "latent heat," &c., are capable of exact definition in a manner which enables the relations between them to be investigated analytically. These relations thus investigated are found by M. Pictet to be capable of experimental verification, and the complete acccordance of deduced theory with observed fact justifies him in giving the name of *Synthesis of Heat* to this new advance in thermo-dynamics.

To understand aright the views of M. Pictet with respect to the possible dissociation of the metalloids we must notice briefly the fundamental points of his theory of heat. If the atoms of a body are in absolute rest and equilibrium, their temperature will be at *absolute zero*. If however, kinetic energy is imparted to these atoms and they are set vibrating, the *temperature* of the body will be represented by the *mean amplitude* of the oscillations, and the total *quantity of heat* in the body will be the quantity of energy thus imparted.

Now the great decomposing force in nature is heat. It is heat which changes solids to liquids, liquids to vapours. Heat breaks up chemically combined substances and reduces them to simpler forms. It is quite certain that the limits of the power of the chemist to decompose the substances that pass through his hands are those which correspond to the temperatures which he can produce in his laboratory. We shall explain at a later portion of this article how this comes to be the case. Yet there are in nature temperatures far more elevated than the highest artificial temperature. To take the most striking example, the surface of the sun must be enormously hotter than even the hottest of the electric arcs in which even the most infusible of metals is vaporised. We know this upon evidence which accumulates evety day, and of which the most important is that afforded by the spectroscope. The researches of Kirchhoff and J. W. Draper, and the later work of Cornu, Mascart, and Lockyer, establish incontestably that the radiation emitted by a glowing substance varies with the temperature of the substance, and that at higher temperatures new rays of shorter wave-length and more rapid oscillation appear, while the intensity of all the emitted rays is also greater. The solar spectrum is much more rich in violet and ultra-violet rays at the more refrangible end of the scale than the spectrum of any artificially heated substance. The irresistible conclusion is that its temperature is far higher.

But the spectrum of the sun when scrutinized with the most elaborate skill and knowledge reveals another very striking circumstance. A large number of the substances regarded by the chemist as *elements* have now been recognised by the characteristic absorption lines of their spectra as existing in the heated matters surrounding the sun. The researches of Mr. Lockyer show that nearly forty of the metals are thus to be detected. But *not a single metalloid* is thus discoverable. Indeed so marked is their absence that the presence of hydrogen in such great abundance is held by no less an authority than Mr. Dumas to be a convincing proof that hydrogen is a metal and not a metalloid. It is true that Mr. Henry Draper of New York, has announced the discovery of *bright* lines corresponding to oxygen amongst the dark absorption lines of the solar spectrum: but it is far from certain whether the coincidence he has pointed out is real or apparent only, and all other evidence points to an adverse conclusion.

Putting together these two capital facts of solar spectroscopy, the irresistible inference is that the surface of the sun is too hot for metalloids to exist there; or in other words, *its temperature is higher than the temperature of the dissociation-points of the metalloids.* This term dissociation-point is justified by analogy with the terms boiling-point and melting-point, with which we are familiar, and with which we associate the notion of definite temperatures.

Let us examine, following M. Pictet's fundamental principles, how far this analogy can be followed out and justified. Those fundamental principles are that in hot bodies the molecules are swinging to and fro about positions of equilibrium; that "heat" *is* the energy of these molecular vibrations; and that the "temperature" of the body *is* the mean amplitude of the vibrations. If more energy is imparted to a solid, the more energetically will its particles oscillate, the longer will be the mean amplitude of their oscillations, and the higher the temperature. If we allow that the gravitation law of attraction, namely that the attraction between two masses varies inversely as the square of the distance between them, holds good not only on the grandest scale but also on the most minute, we must admit that the force acting on a vibrating particle at the furthest limits of its swing, and tending to attract it back, will be relatively weak as the amplitude of the swing is great. Hence too long a vibration may carry the particle right beyond the field of molecular attraction; and the particle will not return but will carry off with it in the form of potential energy part of the heat furnished to the body. The sum of these small quantities of potential energy which must necessarily disappear from the body during its change of state from the solid to the liquid condition constitute that which we usually term "latent heat."

Now consider a solid body at the absolute zero of temperature to which new quantities of heat are continuously imparted. What will be the successive changes to be observed? At first the temperature of the body will rise proportionately to the quantity of heat imparted to it. When the vibrations of the particles have attained a certain amplitude, fusion will take place, not all at once but gradually, each molecule passing away from the attraction of its neighbours, as soon as its vibration is sufficiently energetic. Each solid particle will thus be split up into two or more liquid molecules exactly resembling each other. Every one of these molecules will require potential energy, hence during the entire process of liquefaction, the whole of the heat imparted will be employed in producing the change of state; so that the temperature will be stationary in spite of the continual addition of heat. But when the whole substance has melted, the temperature will again rise up to a certain point determined by the commencement of ebullition, a point which will vary with the conditions of external pressure. This second change of state arises from a further splitting up of the molecules into two or more portions each, every separated portion again carrying off with it a further quantity of potential energy, the "latent heat" of vaporisation. If the gaseous molecules thus produced receive still further quantities of heat, the temperature will go on rising until another point is reached, corresponding to a first chemical *dissociation*, when, as the lengths of oscillations become excessive, the separate atoms are successively thrown apart. This process, like those of liquefaction and vaporisation, will be accompanied by the absorption of heat. The extent to which energy must be furnished in order thus to produce chemical separation, will be proportional to the chemical affinity of the separated atoms; and if the body consists of several chemical constituents it is probable that some of these will be dissociated at lower temperatures and some at higher. The limits of dissociation will have been reached when the body has been separated into its ultimate particles or true elements.

The striking feature of this series of changes is that while the addition of quantities of heat goes on continuously, the rise of temperature is discontinuous, having several stationary points in the range between the absolute zero and the highest possible temperature; each fresh stationary point corresponding to a change of state, or a decomposition of the particles into simpler forms.

Suppose next that we could reverse the order of operations, and could abstract the heat continuously from the dissociated bodies, we might expect to find the same series of changes occurring in the inverse order. But this expectation would not be realized, for reasons which are not difficult to find. In the two changes of state which are of a nature usually termed *physical changes*, namely liquefaction and vaporisation, the result of the splitting up is to produce particles all of the same kind. In a liquid—water, for example—all the liquid particles are water. In a vapour—steam, for example—the particles are all particles of steam. But in the case of *dissociation*, which is a *chemical* change of state, the result of the splitting up is to produce particles not all of the same kind. Thus, if steam is passed through a white hot platinum tube, the dissociated matters are of two kinds, oxygen particles and hydrogen particles. In the changes denominated "physical" which produce homogeneous particles, the recombination does not depend on the relative *positions* of the constituents but only on *pressure* and *temperature*. In the changes denominated "chemical" which, as we have seen, produce heterogeneous particles, the recombination of the constituents depends on their relative *positions* and on the way in which they have to be grouped in the compound, as well as on pressure and temperature. This most important distinction must not be overlooked.

Again, the dissociated chemical atoms carry away with them in a potential form the heat which has disappeared during the process of dissociation, exactly as a liquid carries in a potential form the "latent heat" which disappeared during the process of liquefaction. If we collect the separated chemical constituents—the oxygen and hydrogen for example—and make them recombine, they will evolve this potential energy and the heat will reappear. The limit of temperature, therefore, which can possibly be reached by the combustion or chemical combination of any bodies is precisely the temperature of the dissociation point of the substances formed. Hence there is obviously, as we remarked at the outset, a limit to the power of the chemist to dissociate bodies; a limit determined simply by the temperatures he can artificially produce.

It will be remarked, however, that we have in the electric current a means of obtaining many decompositions which without its aid would have been unknown to us. We may even assert upon the certain evidence of the spectroscope that the temperatures attained by the electric spark are far higher than those of any known combustion. Nevertheless there are here also limits which cannot be passed. If in the circuit of the most powerful battery we interpose a conductor of considerable resistance its temperature will rise; and, if the conductor be reduced in thickness to augment its resistance, will continue to rise until the conductor itself is either liquefied, volatilised or dissociated, when of necessity a practical limit is reached in the entire stoppage of the current. Again, with the discharges from induction coils and Leyden jars, which take place even across gases, there must be a limit, determined by the absorption of energy by the very molecules which are concerned in the discharge, and whose resistance to the electrical action will increase with their temperature. It is a point which may admit of some further discussion. But, on the whole, one is led to the conclusion that the dissociations we have shown to be theoretically possible are in a very large number of cases absolutely beyond the practical limits of experimental achievement.

One course yet remains open. We have not hitherto considered the connection between temperature and radiation in its bearings upon this question. It appears that every temperature, as defined above, corresponds to a definite kind of radiation. Every calorific oscillation of a particular rate is then associated with the propagation of a wave of disturbance in the surrounding ether; this wave having a particular frequency, or, what is the same thing, a particular wave-length. When these calorific waves in passing through space meet a body they tend to set its particles vibrating; and, what is more important, tend to set them vibrating in unison with the original vibrations of the radiating source. If it were not that the receiving body were subjected to external influences, it would acquire little by little exactly the same temperature as the body from which the radiations were emitted. In other words thermic equilibrium would be established between the two, quite irrespective of the distance between them. We know that the rays of the sun traverse space without any diminution in their frequency or wave-length. It follows, therefore that *the sun's rays are able to raise to a temperature equal to that of the sun's surface any body on the surface of the earth on which they can be concentrated*, provided only such a body could be preserved from losing heat by conduction or radiation. Although a certain quantity of the solar radiation is arrested by absorption in the imperfectly transparent atmosphere surrounding the earth, measurements made at places so widely apart as Cairo, Paris, and St. Petersburg agree in showing almost identical values for the amount of heat received from the sun, and which is about twelve calories, per square metre, per minute.

Now on the supposition that all the metalloids, with the exception, perhaps, of oxygen, are dissociated in the sun, thermal equilibrium, if thus experimentally obtained, ought to affect the dissociation of them upon our globe also.

M. Pictet therefore proposes that an enormous parabolic mirror should be constructed, in the focus of which the sun's rays should be concentrated upon the various metalloids which it is sought to decompose. All the data for calculating the requisite size of the mirror are known to a certain approximative value, with one exception. We know the quantitative intensity of solar radiation, and the reflecting power of polished metals, and hence can calculate how many units of heat a mirror of given size will hurl into its focus per minute. *We do not know* how much heat must be furnished to a given weight of any one of the hitherto undecomposed metalloids to dissociate it, but we are quite certain that this quantity must be much greater than that produced by the combustion of an equal weight of hydrogen and oxygen. Assuming that to dissociate bromine required *a hundred times* as much heat (at the temperature of its dissociation-point) as water vapour requires (at *its* dissociation-point) to split it up, M. Pictet calculates that a single gramme of bromine must have 350 calories expended upon it to resolve it into its elements. Further calculation leads him to consider that to dissociate one gramme of bromine per minute, would require that the solar rays should be concentrated by a mirror of *at least* 35 sq. metres of surface, measured normally to the rays, or of about ten metres' aperture. It would, he thinks, be best constructed in separate pieces of about a square metre in area, each ground and polished to a true curve and mounted in a special frame. The depth of the mirror should be equal to half its aperture, bringing the focus into the plane of the rim. At the focus would be a special *solar chamber*, or crucible, constructed of lime or zircon, or other refractory substance, into which the vapours to be operated upon would be led. To avoid loss of heat it would be kept hot from without by oxyhydrogen flames. The whole apparatus ought not, he thinks, to weigh as much as two tons. To catch and retain the dissociated substances, and to prevent their immediate recombination, he proposes to aspirate the vapours of the chamber through metal tubes containing metallic gauze, and cooled from without to a temperature perhaps as low as—50° by intense artificial refrigeration. The rapid cooling thus produced should hinder at least a considerable proportion of the constituents from recombining as fast as they were liberated from each other in the solar chamber.

There is much that is suggestive in the proposals of M. Pictet; so much, indeed, that any attempt at criticism or comment would outrun the limits of this article, which is therefore simply devoted to the exposition of M. Pictet's ideas in phrases as nearly identical as possible with those in which he has himself expressed them.

S. P. T.

THE DESTRUCTION OF INSECT PESTS, AN UNFORESEEN APPLICATION OF THE RESULTS OF BIOLOGICAL INVESTIGATION

"WHAT is the good of a knowledge of microscopic creatures? What is the good of prying into the anatomy of insects? It is all very well as an amusement, but serious persons can not be expected to assent to the devotion of endowments or state-funds to such trivial purposes. Chemistry, geology, electricity, if you please, have their solid commercial value, but biology is an amusement for children and old gentlemen." Such is the opinion of many a "practical man," ignorant and short-sighted as the genus invariably proves itself.

Already the practical man may be told in reply, that surgery is entirely reformed by our knowledge of the minuter fungi, that by avoiding the access of Bacteria to wounds, we avoid a large destruction of human life; already we see our way to avoiding some deadly diseases caused by these same Bacteria now that we know them to be the active cause of such disease. Already silk is cheaper in consequence of our knowledge of the Bacteria of the silk-worm disease; already better beer is brewed and better yeast supplied to the baker in consequence of Pasteur's discovery of the bacterian diseases of the yeast-plant; already vinegar-making, cheese-making, butter-making, wine-making, and other such manufacturing trades are on the way to benefit by like knowledge. Potato-disease and coffee-disease have been traced to their causes and means suggested by biologists for dealing with the parasitic plants causing those diseases, whereby not thousands but millions of pounds sterling a year may be saved to the community.

Insect pests which have depopulated whole provinces, such pests as the Phylloxera and the Colorado beetle, are about to receive a check at the hands of the same class of scientific students. The application of knowledge of natural facts is in this case a very remarkable one; for it is actually proposed to make use of our recently acquired knowledge of diseases due to Bacteria—not that we may arrest such diseases, but that we may promote them. Insect pests are to be destroyed by poisoning them not with acrid mineral poisons which damage plants as well as the insects, but by encouraging the spread of the disease-producing Bacteria which are known to be fatal to such insects. Prof. Hagen, of Cambridge, Mass., has called attention to the old practice of destroying greenhouse pests by the application of yeast. He conceives that this method may be applied to other insect-pests, such as Phylloxera, Colorado beetle, cotton worm, &c. He imagines that the yeast-fungus enters the body of the insect on which it is sprinkled and there produces a growth which is fatal to the insect's life. It is a well-known fact that insects are very subject to fungoid diseases and it is also ascertained that the application of yeast to the plants frequented by such insects favours their acquisition of such disease. Prof. Elias Metschnikoff, the celebrated embryologist, has however made some investigations on this subject and given an explanation of the possible value of yeast application (*Zool. Anzeiger*, No. 47), different and more satisfactory than that which Prof. Hagen appears to adopt.

The general result of the most accurate investigations of the beer-yeast fungus (*Saccharomyces cerevisiæ*), is entirely opposed to the notion that it can enter an insect's body and produce a disease. Beer-yeast is beer-yeast and appears always (or within experimental limits) to remain so. On the other hand De Bary has made known the life history of some simple fungi which destroy insects,